MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XLIII. NOVEMBER 10, 1882. No. 1.

E. J. STONE, M.A., F.R.S., President, in the Chair.

Prof. H. G. van de Sande Bakhuyzen, The Observatory, Leyden;
Dr. W. Döllen, The Observatory, Pulkowa;
Dr. W. Klinkerfues, The Observatory, Göttingen;
Prof. H. Schultz, The Observatory, Upsala; and
Prof. H. C. Vogel, The Observatory, Potsdam,

were balloted for, and duly elected Associates of the Society.

Robert Bryant, 11, King Street, Tower Hill, E.C.;
Captain Arthur Lister Kaye, Manor House, Stretton-on-Dunsmore, Rugby; and
Jonadab Finch, Cheltenham,

were balloted for, and duly elected Fellows of the Society.

On certain Deviations from the Law of Apertures in Relation to Stellar Photometry; and on the Applicability of a Glass Wedge to the Determination of the Magnitudes of Coloured Stars. By Professor C. Pritchard, F.R.S.

I believe the Society is aware that for some time past I have been engaged in the photometric examination of the relative brightness of the stars, by means of an instrument which, though not new in its several component parts, claims to be entirely new in their combination and mode of application. The first section of the work is now all but completed, viz. that which includes the relative brightness of all the stars from the Pole to the Equator,

which, in the catalogue of Heis, are estimated as brighter than the fifth order of brightness; together with a few other stars, possessing features of interest.

In the course of this research, some facts of considerable importance, and, as I think, possessing some novelty, having presented themselves, I take this opportunity of communicating them to the Society.

At an early stage of the inquiry, a doubt arose in my mind as to the perfect accuracy of the law which expresses the ratio of the amount of light successively transmitted by varying the aperture of the same object-glass. In my method of stellar photometry, the accuracy of this law was assumed as exact; and, indeed, formed a most material element in the reduction of the observations. For I had determined from several hundred measures, that a certain thickness of neutral-tinted glass, indicated by a measured interval along the wedge, reduced the light of a star by the same amount as that which is extinguished by halving the aperture of the object-glass; according to the generally accepted theory, this reduction of light is in the proportion of four to one. And in this way I was led to that method of reducing the wedge observations which has been already explained to the Society in my communication of November last, just twelve months ago.

I had reason to doubt the strict accuracy of this law, both from the nature of certain resulting deductions which forced themselves on my attention, and from the consideration that the complex structure of an object-glass consists virtually of a series of reversed wedges of two different kinds of glass differing in their thickness. Moreover, I had also been somewhat startled at conclusions arrived at by Dr. Wolff, of Bonn, in his photometrical observations published at Leipzic 1877. Dr. Wolff, in this really valuable and interesting work, states that he used a Zöllner Photometer, after having submitted it to the necessary tests. Among these tests he compared the ratio of the light transmitted from the same star through telescopic apertures varying approximately in the ratio of 3, 2, 1: the ratio of the lights so transmitted would, he expected, be in the ratio of 9, 4, 1; but as exhibited by the Zöllner Photometer, these ratios came out utterly, and as it seemed hopelessly, discordant., as will be seen from the exact figures given below.* Whether the causes which led to this most unexpected and discordant result, are rightly conjectured by Dr. Wolff or not, the fact remains; and, if unexplained or disregarded, would seem to suggest some preliminary doubts either as to the

* The exact diameters of the several apertures of the object-glass were respectively 37·4 mm., 25·9 mm., and 13·9 mm. From these figures Dr. Wolff calculates that the logarithmic ratio of the light of a star as seen with the two foregoing apertures of 37·4 mm. and 13·9 mm., should be 0·8766 [qu. 0·8597], whereas the ratio derived from actual observation was 0·3384. The numbers corresponding to these logarithms are respectively 7·53 [qu. 7·24] and 2·18: that is, the actual instrumental result was about $3\frac{1}{2}$ times less than it should have been on the generally adopted theory of apertures!

competency of the instrument, or as to the validity of the methods employed. I was quite sure that in the case of my own inquiries no such deviation from the generally received law of apertures could possibly exist; but, nevertheless, it now was more than ever necessary to determine, for the purposes of my own research, the exact ratio of the light transmitted by varying the aperture. I had in fact assumed, as other astronomers had assumed before me, that by halving the aperture, one-fourth part of the light was transmitted.

The late Mr. Johnson also undertook a series of experiments in nearly the same direction. He found that one of the halves of the heliometer objective transmitted more light than the other half, in the ratio of 1000 to 924; and further, that probably the central parts of the objective of the Oxford Heliometer are more transparent than the parts near to the circumference. The consequences of this latter result, however, he does not pursue further; but, notwithstanding his suspicions, he assumes throughout his investigations on the magnitude of certain stars, that the strict accuracy of the commonly received law of apertures is maintained.

Under these circumstances it was necessary, for the purposes of establishing the exactness of my photometry, to institute some crucial experiments, if such could be devised.

The first process which suggested itself to my mind was to ascertain, by means of my wedge, the relative amount of light transmitted 1° by the full aperture of 4 inches; 2° by the reduced aperture of 2 inches; and 3° by the full aperture, having a circular patch of two inches in diameter in the centre. This process must lead to the solution of the question before us, as will be obvious on a consideration of the case. But, instead of having recourse to this method of investigation, which, to be efficacious, would necessarily require much time and many observations, I thought it better to adopt an independent form of photometric examination, founded on the same principles of double refraction as those which have been so successfully applied by Prof. Pickering at Harvard College, and suggested in the *Observatory* of August 1882.

The method itself appears to me to be one of great beauty, readiness, and accuracy. It consists, mainly, in comparing the amount of light transmitted at different successive points on the wedge, by means of a double-image prism of quartz and a Nicol prism. The wedge was thus examined at every tenth of an inch throughout its extent, and its general uniformity was established to a degree which I had hardly ventured to expect. The conclusion I arrived at was, that on this hypothesis of practical uniformity, measures of light carefully made with the wedge ought not to lead to an error exceeding about the thirteenth of a magnitude. The full particulars of these experiments must be reserved until the publication of the complete memoir on the photometry of the brighter stars of the northern hemisphere is

B 2

communicated to the Society. For the present, the following results, and explanation of the method employed, may be interesting and sufficient. An opaque moveable screen was placed over the wedge, and in this screen two rectangular apertures were cut, whose centres were distant from each other by 0·3741 inches; the breadth of each of the apertures was 0·022 inches. Parallel light was then transmitted through the wedge at these two apertures, either from the Sun or from a gas lamp (and in a subsequent series of experiments through coloured glasses or coloured liquids); the ratio of the emergent lights through these two apertures was then measured by the double-image photometer, and the results are given in column 2 of the following table.

Wedge A, for use with a 4-inch Telescope.

Successive Positions of Screen. inches.	Mean Light Ratio.	Error of the Mean.	Equivalent Magnitude. (Pogson's scale.)	Error of the Mean in Magnitude.
From 0·3 to 0·9	1·919	0·026	0·71	0·015
1·0 „ 1·9	1·885	0·037	0·69	0·022
2·0 „ 2·9	1·901	0·031	0·70	0·019
3·0 „ 3·9	1·903	0·028	0·70	0·017
4·0 „ 4·9	1·889	0·027	0·69	0·017
5·0 „ 5·9	1·877	0·031	0·68	0·017

Wedge B, for use with a 3-inch Telescope.

From 0·5 to 1·4	2·443	0·029	0·970	0·012
1·5 „ 2·4	2·448	0·040	0·972	0·018
2·5 „ 3·5	2·445	0·036	0·971	0·016

Column 1. These figures mean (taking the first line as an example) that the wedge was photometrically tested at every tenth of an inch throughout the interval of wedge beginning at 0·3 in. from the end and ending at 0·9 in. towards the thicker part. Column 2 gives the mean of the ratio of the light transmitted at each successive tenth of an inch; as, for example, when the screen was moved from 0·3 in. to 0·4 in., to 0·5 in., up to 0·9 in. Column 4 is column 2 expressed in magnitude, assuming the light ratio for a single magnitude to be 2·512. Columns 3 and 5 explain themselves.

A further discussion of the results thus obtained leads also to the ratio of the light transmitted by the two telescopes employed when their linear apertures were halved. This ratio in the case of the 4-inch telescope is 3·918 : 1. In the 3-inch telescope this ratio is 3·921 : 1. These ratios approximate to the ratio of 4 : 1, hitherto I believe universally adopted; but, nevertheless, the error which would be thus introduced in the photometric reduction is by no means inconsiderable. For example, in the comparison of two stars differing by only three orders of brightness, the error thus

introduced would amount to nearly a tenth of a magnitude, an amount of error which is not admissible in the accurate photometry aimed at, and shown to be attainable by my method. Indeed, this deviation from exactness was sufficient to compel me to modify the reduction of the observations of several hundreds of stars. Moreover, it is of the nature of a systematic error, and would probably become greatly increased and very serious, if the aperture of the telescope were still further reduced to those much smaller dimensions (one-seventh of an inch for example) which have been recommended by preceding astronomers. Further, these investigations seem to suggest that it would be impossible to apply any method of telescopic apertures alone, to the photometry of the stars, unless the idiosyncracies of the particular object-glass employed were accurately ascertained by some independent method of photometry.

While I was engaged in the foregoing inquiry into the capacity of the wedge as regards the amount and uniformity of its absorption of ordinary light, I availed myself of the opportunity of examining its effects on lights of different colours; and this I did with the expectation of ascertaining how far the wedge method of photometry could be relied on in the case of coloured stars, whether single or double. With this view I interposed coloured glasses and other coloured media between the source of light and the wedge, and I ascertained, as the result, that within the limits of our unavoidable errors of observation the same thickness of wedge practically absorbed the same amount of light, whether its colour be red, orange, yellow, green, or blue. I confess that I was agreeably surprised at this result, although I think that, in part at least, it might have been anticipated; because, in the process of extinguishing the light of stars through the wedge, there had been no consciousness in the mind of the observer, of different colours in the case of particular stars. If this result be confirmed, as I think it will be, by still more numerous observations, it is obvious that in the wedge we possess an instrument applicable to the photometry of coloured stars. It may here be interesting to give a few numerical results.

The mean absorptive power of the wedge B for different moderately coloured lights, obtained by the process referred to in Table I., is as follows:—

White light from Sun	2·445 = 0·97 mag.
Red light	2·432 = 0·96
Orange	2·436 = 0·97
Green	2·426 = 0·96
Blue	2·421 = 0·96

The characters of these various media were examined *spectroscopically*, with the following results. The band of absorption extended, in the case of the

Red medium; from wave-length	527	to w.l. 468,	*i.e.* E to $\frac{1}{2}$ (F+G)
Orange medium;	518	,, 420	,, *b* to G
Green medium;	691	,, 590	,, B to D
Blue medium;	760	,, 653	,, A to C

In still further confirmation of the applicability of this method of stellar photometry I may place a few observations of coloured double stars made at Oxford with the wedge now referred to, in juxtaposition with observations of the same stars made at Harvard College by Professor Pickering with his double image photometer.

Star's Name.	Colours of Components. A	B	Difference of Magnitude. Wedge (Oxford)	Double Image (Harvard)	Σ's estimation.
η Cassiopeia ...	*y*	*p*	3·77	3·85	3·6
ψ′ Piscium ...	*w*	*w*	0·22	0·20	0·3
ζ Piscium ...	*w*	*w*	0·86	0·96	1·1
γ Andromedæ .	*gl*	*b*	2·72	2·85	2·0
α Piscium ...	*g*	*b*	0·97	0·90	1·4
Castor ...	*grsh*	*grsh*	0·75	0·82	1·0
α Can. Ven. ...	*w*	*w*	2·33	2·56	2·2
ε Boötis ...	*v.y*	*v.b*	2·46	2·43	3·3
ζ Lyræ ...	*gr.w*	*gr.w*	1·11	1·38	1·1
ε Lyræ ...	*gr.w*	*bl.w*	1·01	0·96	1·7
5 Lyræ ...	*v.w*	*v.w*	0·36	0·23	0·3
θ Serpentis* ...	*y*	*y*	0·33	0·87	0·1
β Cygni ...	*y*	*b*	1·74	2·14	2·1
β Cygni (Nov.6)			1·82		
γ Delphini ...	*gl*	*bg*	0·93	0·99	1·0

There remains another question for consideration, viz. the effect of the atmosphere on the light of the stars as seen at varying altitudes. In my first communication to the Society I cursorily touched upon this point, and I thought I had satisfied myself that, for stars observed at altitudes exceeding 50°, the difference in the amount of the atmospheric extinction of light is so small that it can be allowed for or even disregarded without appreciable error; but that at lower altitudes the effects are so variable, and seem to depend upon elements so inconstant, at all events in our climate, that very sensible errors may easily be admitted from this cause. Dr. Seidel's tables do probably represent

* Looking at Professor Pickering's individual measures, it seems probable that one of the components of this star may be variable.

average results, but do not seem to be available in individual cases. Dr. Wolff goes so far as to state that, in his particular locality, he regards even the azimuth of a star to be an element in the amount of stellar light extinguished. This may be the case at Oxford also, possibly owing to the confluence of so many streams of water. And this suspicion is by no means to be disregarded in reference to our own method of observation; because this method, in part, consists in not observing stars necessarily on the meridian, but in such positions as shall best secure a general uniformity in the altitudes of all the stars observed. Considering the difficulty and importance of this branch of the subject, and the necessity of varying both the meteorological and the geographical conditions under which the observations should be made, I purpose to undertake a journey to the south, probably to Cairo, in order to collect additional information for the solution of the problem, and to render this contribution to stellar photometry as complete as possible.

In what has been herein advanced, regarding

(1) The caution that is now shown to be necessary before adopting a method of photometry by varying telescopic apertures;
(2) The possibility of securing practical accuracy of stellar photometry in the use of a wedge of neutral-tinted glass;
(3) The possibility of correctly measuring thereby the relative brilliance of coloured stars, whether single or double,

I hope something useful has been added to our astronomical methods of research.

On Observations of Comets 1881 *II. & III., of Wells's Comet, and of the Great Comet* (b) 1882, *made at the Royal Observatory, Cape of Good Hope.* By David Gill, LL.D., Her Majesty's Astronomer at the Cape of Good Hope.

The following papers contain all the observations of comets made at this Observatory since 1880, with the exception of a few observations of Wells's Comet, made with the heliometer, and those of the present Great Comet, which are not yet reduced.

In April 1881, when on a brief visit to England, I took with me, and forwarded to Messrs. Repsold, of Hamburg, the tube of the $8\frac{1}{2}$-foot equatorial, for the purpose of having a new micrometer and new illuminating arrangements made for it.

During my absence, and whilst the tube was with Messrs. Repsold, Tebbutt's Great Comet appeared, and it was admirably